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Snow Accumulation and Melt in Sprayed and Undisturbed Big Sagebrush Vegetation

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The influence of big sagebrush control on snow accumulation and melt was studied in a location where wind is an important snow relocation agent. A small (≤5 cm) but significant reduction in snow accumulation was detected before vegetation was covered by snow on plots sprayed with 2,4-D compared to plots with untreated vegetation.

Sagebrush control had no effect upon maximum depth of snow accumulation or snowmelt rates. Snow deposition at the experimental site was controlled by topographic factors once snow depth exceeded vegetation height.

Keywords: *Artemisia tridentata*, snow accumulation, snowmelt.

Snow accumulation and melt characteristics on sagebrush lands have not received the attention given to forested lands. An early study by Connaughton (1935) in Idaho showed that snow accumulation characteristics on a plot denuded of vegetation was similar to a plot with big sagebrush (*Artemisia tridentata*) vegetation. A stand of mature timber accumulated only about 75% as much snow as bare or sagebrush plots because of interception losses. Melt rates on bare and sagebrush plots were almost identical, but plots with a forest cover retained snow 4 to 8 days longer depending on canopy density.

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Sonder and Alley (1961) were the first to describe the effects of big sagebrush control on snow accumulation. They reported no difference in accumulation for sprayed and unsprayed vegetation in the Red Desert of Wyoming where drifting is common. At another study location in the Bighorn Mountains of Wyoming, sprayed vegetation retained snow longer in the spring than unsprayed vegetation. Snow measurements were taken once in the spring, 6 and 7 years after control. Snow depth was 60 centimeters in the sprayed sagebrush stand and 20 centimeters in the unsprayed sagebrush stand in the sixth year after spraying. The following year, snow was 25 and 21 centimeters deep on the sprayed and unsprayed areas, respectively.

Intensive snow depth and density measurements were taken by Hutchison (1965) on adjacent plots dominated by mountain big sagebrush (*A. t.* sub. *vaseyana*) and grasses at a site 2,900 meters in elevation in northwest Wyoming. The

plots were on level ground to minimize snow trapping due to topography. Even though drifting was minimal, sagebrush plots accumulated significantly more snow early in the winter because sagebrush crowns caused greater snow deposition. Accumulation rates were similar for both types of vegetation once sagebrush crowns were covered, but the initial difference in depth persisted through the winter. Average melt rates determined over an 8-day period were also similar, 0.97 and 1.14 centimeters per day for grass and sagebrush vegetation, respectively.

Methods

This report describes a plot study that was conducted to learn if spraying big sagebrush affects snow accumulation, maximum snow depth, or the snowmelt rate. A continuous record of snowmelt was also obtained during two springs from a snowmelt lysimeter located in undisturbed big sagebrush vegetation.

Work was performed at the Stratton Sagebrush Hydrology Study Area located in southcentral Wyoming, 29 kilometers west of Saratoga. The Stratton area is 2,225 meters in elevation and receives about 500 millimeters of precipitation annually. About two-thirds of total precipitation falls as snow; accumulation begins in November, and melt begins in April or May. The average monthly windspeed increases from about 22 kilometers per hour in November to 32 kilometers per hour in January, and then progressively decreases to 19 kilometers per hour in April. Because of strong winds, much of the snow that falls is quickly relocated from windward slopes and ridges into natural accumulation zones. The location of accumulation zones is controlled by the topography in combination with prevailing wind direction.

The experimental site was in a moderate snow accumulation zone on the lower portion of a north-facing hillside. A dense stand (47,100 plants per hectare) of mountain big sagebrush was present at the study site before treatment. About two-thirds of the sagebrush plants were between 30 and 50 years old. Individual plants averaged 34 centimeters tall, and the stand had a live, leafy crown intercept of 28%. Total herbaceous production was 1,423 kilograms per hectare the year before spraying. Sagebrush contributed 73% of total production; 23% was contributed by grasses, and the remaining 4% was contributed by forbs. Idaho fescue (*Festuca idahoensis*) and various bluegrasses (*Poa* spp.) were the dominant grass species.

Fourteen 0.4-hectare plots were established on the hillside in 1968. The plots were located in two strips that were 8 and 6 plots long, arranged in a randomized block design. Each block consisted of two plots that were randomly assigned to either the spray or nonspray treatment. Plots also were utilized to study the effects of sagebrush control on the soil moisture regime (Sturges 1977).

Snow accumulation decreased up the hillside because of an interaction between site location and prevailing wind direction. Consequently, average plot snow depth was determined from measurements made along one transect that was perpendicular to the slope and another that was parallel to the slope. Seven snow depth measurements, spaced at 9-meter intervals, were taken on each transect. Measurements were made about once a month through the accumulation period and more frequently during the melt period. A variance analysis, based on average plot snow depth, was performed for each measurement date. Treatment differences were accepted as statistically significant at the 0.05 probability level. Snow density was determined only at a single point near the center of each plot on each measurement date to indicate average density across the experimental site.

Snow accumulation was measured during the winter of 1969-70 to identify variability in snow deposition at the site before sagebrush control. Posttreatment snow measurements were made during the snow accumulation phases of the winters of 1970-71, 71-72, and 72-73, the first through third winters after sagebrush control. Intensive snow depth measurements were made during the 1971, 1973, and 1974 snowmelt seasons.

Treatment plots were sprayed with 2,4-D in June 1970, killing more than 95% of the plants. Remaining live plants were hand sprayed the following spring to achieve as complete a control as possible. Sagebrush skeletons were left intact, and, except for small branchlets, little breakdown of skeletal material had occurred by the fourth posttreatment winter.

Daily Snowmelt

A continuous record of snowmelt was obtained during the 1973 and 1974 melt periods using a snowmelt lysimeter patterned after the instrument designed by Haupt (1969). The meter was located on an unsprayed plot where snow accumulation was similar to average accumulation on all untreated plots. The meter was 61 centimeters square, but was modified from Haupt's design by enclosing a sagebrush plant within the meter and by using butyl rubber to form the bottom of the lysimeter. The sagebrush plant was about 40 centimeters tall, and its canopy covered approximately two-thirds of the meter area. Plastic sheeting was attached to the metal plot boundary and formed the lysimeter walls; the sheeting was pulled up periodically during the winter to isolate the snow column over the meter. Plastic that extended above the snow surface was cut away frequently during the melt season to minimize the lysimeter's effect on microclimatic conditions. Melt water drained from the meter to a storage reservoir. A FW-1 water level recorder was placed on the reservoir to provide a continuous record of inflow.

Results

Snow Accumulation Characteristics

Pretreatment.—Snow accumulation characteristics reflected topographic location of the experimental site in relation to wind speed and direction, vegetation height, and precipitation. Snow accumulation began in early November, and maximum depth was measured April 18 (table 1). Winter precipitation was the lowest recorded during any year of study.

Pretreatment measurements indicated that snow depth was slightly greater on plots that were to receive the spray treatment than on plots that were to remain in an undisturbed state (table 1). However, differences were not statistically significant. Treatment differences ranged from 1 centimeter, on the first measurement date when snow was about 30 centimeters deep, to 3 centimeters, when snow depth exceeded 60 centimeters. Any differences evident after spraying are attributable to sagebrush control.

The relative influence of vegetation and topography on snow accumulation changed as the winter advanced. Plot snow depths were relatively uniform early in the winter while sagebrush extended above the snow surface and little snow was transported onto the experimental site. Large differences developed, however, after sagebrush was covered by snow and accumulation became largely a function of location on the hillside. By March, snow was about 45 centimeters deep on the set of plots that straddled a slight ridge, and about 80 centimeters deep where deposition was most pronounced (table 1).

Table 1.—The range and average snow depth (cm) for plots assigned to spray and nonspray treatments, and average snow density, the winter before spraying.

Date	Range		Average		Snow density
	Nonspray	Spray	Nonspray	Spray	
11/09	23-36	24-42	30	31	0.25
02/05	48-67	41-81	57	58	.34
03/05	41-76	46-85	60	63	.33
03/16	42-78	48-86	61	64	—
04/18	65-100	70-109	86	89	.34
05/08	7-54	19-70	41	45	.40

Posttreatment.—Snow depth on untreated plots the first measurement date after spraying was nearly the same as on the first measurement date the winter before treatment. However, sprayed plots had 2.5 centimeters less snow than untreated plots, the reverse of accumulation characteristics before spraying (fig. 1). When snow was next measured on January 13, sprayed plots had 76 centimeters of snow, 3 centimeters more snow than on unsprayed plots. Once sagebrush was covered by snow, the accumulation pattern reverted to that evident before spraying.

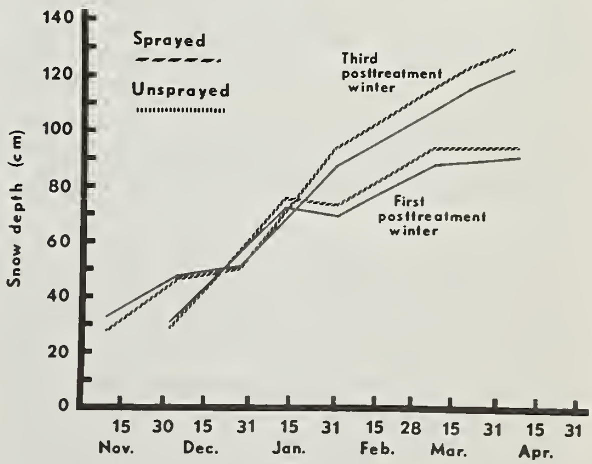

Figure 1.—Snow accumulation for sprayed and unsprayed sagebrush treatments the first and third posttreatment winters.

The first measurement taken the second winter after treatment, on November 5, 1972, indicated that snow was significantly deeper on unsprayed plots (20 centimeters) than on sprayed plots (17 centimeters). The treatment difference decreased to 1 centimeter December 10, when snow was about 45 centimeters deep. At that time, topography had begun to strongly influence deposition of wind-blown snow because vegetation was nearly submerged in the snowpack. Snow was about 70 centimeters deep on January 7, and the accumulation pattern on individual plots had reverted to that evident before spraying.

Data collected the third posttreatment winter verified that accumulation of snow on sprayed plots early in the winter was significantly less than on unsprayed plots (fig. 1). Unsprayed plots had 5 centimeters more snow than sprayed plots November 9, 1973. Thereafter, the rate of snow deposition was greater on sprayed plots as vegetation exerted less and less influence on accumulation. By December 28, the snow surface was at the top of sagebrush crowns, and unsprayed plots had only 1 centimeter more snow than sprayed plots. Snow depth increased more than 35 centimeters in the next month, and accumulation patterns reverted to those evident before spraying when topography was the primary factor controlling deposition once vegetation was covered.

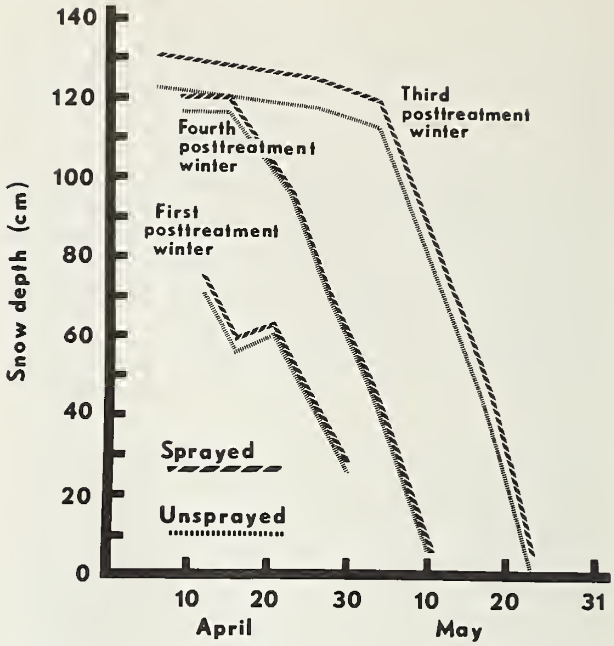

Figure 2.—Snow depths for sprayed and unsprayed sagebrush treatments during the melt period.

Snowmelt Characteristics

Pretreatment.—The difference in average snow depth at the time of maximum accumulation on plots assigned to spray and nonspray treatments persisted through snowmelt. Snowmelt was similar on all plots between April 18 and May 8 (table 1). Measurements indicated that snowmelt characteristics, as well as accumulation characteristics, were similar for treatments before sagebrush control.

Posttreatment.—Sprayed plots always had slightly more snow at the time of maximum accumulation than unsprayed plots, but a similar difference also was evident the winter before spraying. The small, but nonsignificant difference, persisted through the melt period. Snowmelt began between early April and early May in the three springs that intensive measurements were taken (fig. 2). Snow disappeared rapidly every year, regardless of the time that melt began.

The similarity in snow depth through the melt period each spring on sprayed and unsprayed plots suggests that treated and untreated plots had similar melt rates. There were two intervals (10 and 4 days long) in the 1971 melt season and two intervals (6 and 7 days long) in the 1973 melt season when it was possible to directly compare the change in snow depth. Treatment differences were not significant for any period. In 1971 there was a 1 centimeter difference between treatments in both measurement intervals, and treatments lost identical amounts of snow in the two intervals during 1973.

Snow still covered the vegetation during the 1971 and 1973 analysis periods. Therefore, these analyses did not provide a definitive test of whether or not the rate of snowmelt was affected by sagebrush control when the snow surface was within the vegetation canopy. To insure that snowmelt was being influenced by plot vegetation, data were segregated into intervals when (a) plot snow depth was no deeper than 70 centimeters at the beginning of the interval and (b) at least half the measurement points on a plot were snow covered at the end of the interval. Data meeting these prerequisites were available just for the 1971 melt season and then only for five of the seven blocks (table 2). The variance analysis

removed climatic factors as a source of variation before testing for a treatment difference. Unsprayed plots lost an average of 32 centimeters of snow while sprayed plots lost 31 centimeters of snow, a nonsignificant difference. There is no evidence from this study to indicate that spraying had an appreciable effect on snowmelt at any time during the melt interval.

Table 2.—The influence of sprayed and unsprayed vegetation on snowmelt in 1971 when snow was located within the vegetation canopy.

Interval		Change in depth (*cm*)	
From	To	Unsprayed	Sprayed
4/30	5/05	29	26
4/21	4/30	35	37
4/21	4/30	36	36
4/02	4/12	21	22
4/21	4/30	37	34
Aver.		32	31

Daily Snowmelt

The snowmelt lysimeter was in operation during the 1973 and 1974 melt seasons (fig. 3). Snowmelt started April 25, 1973, 27 days later than in 1974, which is typical of year to year climatic variations in the mountain big sagebrush type. The delayed start of snowmelt in 1973 was combined with extremely high melt rates and triggered flow over the snow surface, an unusual hydrologic phenomenon first described on the Stratton Study Area (Sturges 1975).

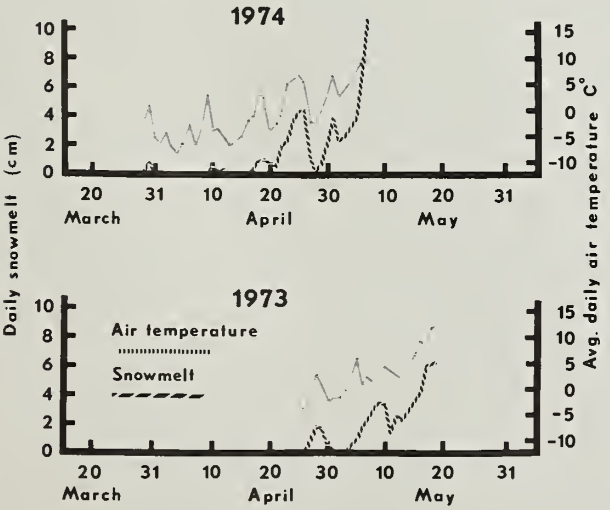

Figure 3.—Daily snowmelt at the snowmelt lysimeter in 1973 and 1974.

Melt commonly released 2 centimeters of water a day while snow covered the sagebrush plant. The rate of melt accelerated sharply when the snow surface reached the sagebrush crown; about 6 centimeters of water a day were released on the last two full days of melt in 1973. The acceleration in melt was caused by a change in energy relations once vegetation protruded through the snow. A continuous snow surface reflects much of the incoming solar radiation, but vegetation efficiently absorbs short-wave radiation. Vegetation then conducts heat directly to the snow. More important, short-wave energy absorbed by vegetation is reradiated as long-wave radiation, which is readily absorbed by snow. As a result, much more of incoming solar energy is used to melt snow when vegetation extends above the snow surface than when the snow cover is continuous. About 15 centimeters of snow depth-loss was required to release 6 centimeters of water in this study and snow disappeared rapidly once the surface was within the sagebrush canopy.

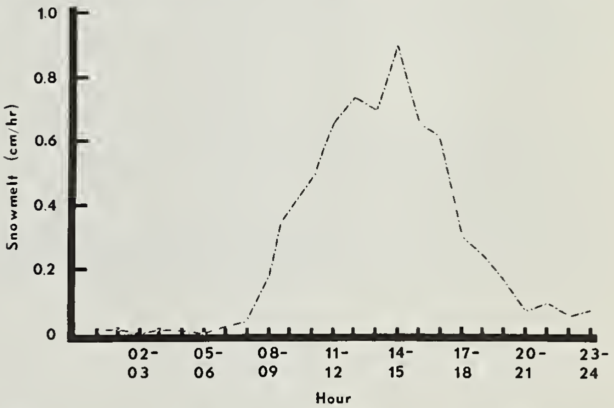

Figure 4.—Average hourly snowmelt rate on three dates when total melt ranged from 6 to 7 centimeters of water per day.

Average hourly snowmelt rates were calculated from data collected on the three days when melt released between 6 and 7 centimeters of water (fig. 4). Though the maximum melt rate was much lower than rainfall intensity during summer convectional storms, it still was substantial. Maximum melt occurred between 2 and 3 p.m. when 0.9 centimeter of water was released. The rate of snowmelt exceeded 0.2 centimeter of water per hour between 9 a.m. and 7 p.m. and exceeded 0.6 centimeter per hour for 6 hours during the day. Thus, the acceleration in melt rate which occurred when the snow surface was within the vegetation canopy was an important but short-lived hydrologic process.

Summary and Conclusions

Snow accumulation was uniform across the experimental site early in the winter when the snow level was below the top of sagebrush plants and snow transport by wind was minimal. Once vegetation was covered by snow, topography and precipitation largely determined additional snow accumulation. Consequently, snow depth on individual plots at the time of maximum accumulation differed substantially even though the study site appeared to have uniform characteristics in a snow-free condition.

Before snow covered the vegetation, snow accumulation was reduced significantly on sprayed plots compared to unsprayed plots. Absolute differences were small, however, and never exceeded 5 centimeters. Accumulation was not affected by sagebrush control once snow covered the vegetation.

The rate of snowmelt was not affected by sagebrush control during the time vegetation was submerged within the snowpack or during the time the snow surface was within the vegetation layer.

A continuous record of snowmelt was obtained from a single lysimeter during 1973 and 1974. Melt rates of 2 to 4 centimeters of water a day were common when snow covered the sagebrush plant, but accelerated to 6 centimeters or more when snow was within the sagebrush canopy. The maximum average hourly snowmelt rate was 0.9 centimeter of water on days when melt released 6 to 7 centimeters of water. Snowmelt exceeded 0.6 centimeter of water per hour for 6 consecutive hours during the day.

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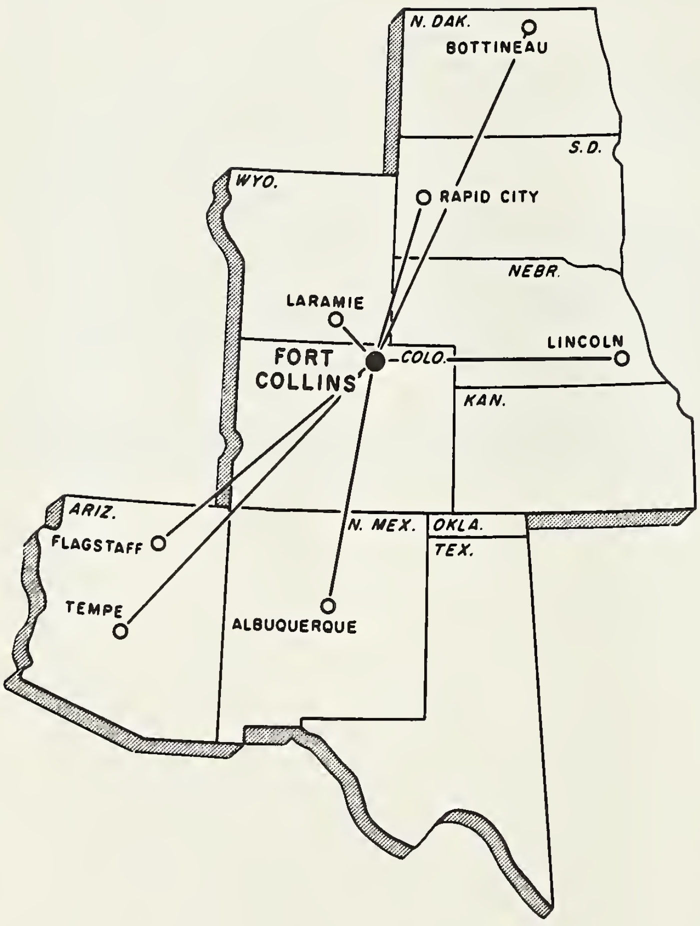
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